THE LIGHT CURVE OF S ANDROMEDAE

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ABSTRACT

Historical observations of S And, in combination with the color versus rate-of-decline relationship for well observed SN 1991bg-like supernovae, are used to estimate a rate of decline Δm_{15} (B) = 2.21 and an intrinsic color at maximum $[B(0) - V(0)]_o = 1.32$ for SN 1885A.

Subject headings: supernovae:individual (S Andromedae)

1. INTRODUCTION

S Andromedae (1885) was probably the nearest extragalactic supernova of Type Ia to have occurred in historical times. A definitive review of the observational material that is available for this object has been given by de Vaucoulers & Corwin (1985). On the basis of its visual light curve, and descriptions of its spectrum, these authors conclude that this object was probably an unusually fast supernova of Type I [modern Type Ia]. This conclusion is consistent with the detection of Fe I absorption at the position of SN1885A by Fesen, Hamilton & Saken (1989). An assignment to modern Type Ia, which comprises stars with progenitors having ages ≥ 1 Gyr, is also supported by the fact that SN1885A occurred only $16''$ from the nucleus of M31, i.e. in a region that exhibits no traces of recent star formation. The pronounced orange color of S And near maximum light suggests that the supernova of 1885 might have been a member of the sub-luminous SN1991bg subclass (Phillips 1993) of SNe Ia. On the other hand van den Bergh (1994) tentatively concluded that the observed colors of S And, during the first weeks after maximum, were intermediate between those of normal SNe Ia and that of the sub-luminous object 1991bg. Since more data on such sub-luminous supernovae have recently become available (Phillips *et al.* 1999, Garnavich *et al.* 2001) it appears opportune to reexamine this question at the present time.

2. LIGHT CURVE OF S ANDROMEDAE

¿From a detailed analysis of over 500 visual observations, that were subsequently tied to nearby modern photoelectric comparison sequences, de Vaucouleurs & Corwin (1985) found that the equation

$$V(t) = 5.85 + 1.65[log(t - t_o)]^2 \quad (1)$$

gives an excellent representation of the visual light curve of S And over the range $6 < V < 14$. Unfortunately little information is available on the color of S Andromedae near maximum light. Only for the period 1885 Sept. 4-8 do de Vaucouleurs & Corwin give accurate color information. An attempt will be made to use a recent compilation of information (Garnavich *et al.* 2001) on other fast red SNeIa to derive (1) the color of S And at maximum light, and (2) the rate of decline Δm_{15} (B) of S Andromedae in blue light.

¿From Equ. (1) it is found that S And had V = 8.13 at 15 days past maximum, i.e. on 1885 Sept. 5.5 ± 1. According to the analysis by de Vaucouleurs & Corwin (1985) S And had a color B-V = 1.31 on this date. It follows that B(15) = 9.44. Unfortunately the data analyzed by de Vaucouleurs *et al.* do not directly give B(0), the blue magnitude of S Andromedae at maximum light. However, it is known that (1) S And was unexpectedly red in the weeks after maximum, and (2) that this object had an unusually high rate of luminosity decline. These factors suggest that S And belonged to the SN 1991bg class of SNeIa. All available photometric data on nine well-observed supernovae that appear to belong to this class have recently been discussed by Garnavich *et al.* (2001). From such data these authors find a well-defined relationship between color at maximum light and rate of decline for sub-luminous supernovae resembling SN 1991bg. Garnavich *et al.* find that nine well- observed objects of this type with $1.7 < \Delta m_{15}$ (B) < 2.0 follow the relation

$$[B(0)-V(0)]_o = 2.38\Delta m_{15}-3.95. \quad (2)$$

This may be recast in the form

$$B(0)_o = V(0)_o + 2.38\,[B(15)_o - B(0)_o\,] - 3.95. \quad (3)$$

From B(15) = 9.44 and A_B = 0.25 mag (van den Bergh 2000) one has $B(15)_o$ = 9.19. Furthermore from V(0) = 5.85 (de Vaucoulers & Corwin 1985) and A_V = 0.19 mag one finds $V(0)_o$ = 5.66. Substituting these values into Equ. 3 and solving for $B(0)_o$ one finds that $B(0)_o$ = 6.98. In conjunction with the value $B(15)_o$ = 9.19 that was obtained above this yields Δm_{15} (B) = 2.21 mag. This value is larger than that of any of the nine SN 1991bg -like SNeIa for which accurate photoelectric photometry is presently available. However, de Vaucouleurs & Corwin point out that an even larger value Δm_{15} (B) was observed for SN 1939b in the E5 galaxy NGC 4621(=M59). From $V(0)_o$= 5.66 and $B(0)_o$ = 6.98 one finds $[B(0) - V(0)]_o$ = 1.32 for S Andromedae. This value is close to the (uncertain) color index $(B-V)_o$ = 1.25 at 15 days past maximum that was obtained by de Vaucouleurs & Corwin. In other words S And appears to have exhibited little color change during the first two weeks after maximum. In this respect S And seems to differ from the prototypical object 1991bg (Leibundgut *et al.* 1993) which had B-V = 0.85 at maximum, but then reddened rapidly to B-V $\sim$ 1.25 by five or six days after maximum.

3. CONCLUSIONS

By combining the observed visual light curve of S And, and its color in early September of 1885, with the color versus rate-of-decline relation of well-observed sub-luminous SNeIa one may estimate the color at maximum and the rate of decline of S And in blue light. Adopting A_V = 0.19 mag , A_B = 0.25 mag and a distance modulus $(m - M)_o$ = 24.4 $\pm$ 0.1 (van den Bergh 2000) for M31, in conjunction with the hypothesis that S And was a

sub-luminous supernova of the 1991bg class, one then finds that, at maximum light:

$V(0)_o = 5.66 \pm 0.5$

$M(0)_V$ = -18.74 ± 0.5

$B(0)_o = 6.98$

$M(0)_B$ = -17.42, and hence

$[B(0) - V(0)]_o = 1.32$

The initial rate of decline in blue light is found to be Δm_{15} (B) = 2.21 ± 0.1 mag. The errors of the magnitudes that are quoted above are not well determined by the observational data obtained in 1885. It is noted in passing that the values of $M(0)_V$ and $M(0)_B$ obtained here for S Andromedae lie significantly above the trend lines in $M(0)_V$ versus Δm_{15} (B), and $M(0)_B$ versus Δm_{15} (B) that were plotted by Garnavich *et al.* (2001) in their Fig.16. By the same token S And lies significantly above the $M(0)_B$ versus $[B(0) - V(0)]_o$, and the $M(0)_V$ versus $[B(0) - V(0)]_o$ relations that Garnavich *et al.* show in their Figure 17. To fit the trend lines shown in their figure our V(0) value for S And would have to be too bright by ∼2.1 mag, or our B-V color at maximum would have to be too red by ∼1.3 mag. Such large values appear inconsistent with the historical data compiled by de Vaucouleurs & Corwin (1985). Taken at face value these results would seem to indicate that there may be significant intrinsic luminosity and/or color dispersion among those SNe Ia having the fastest rates of luminosity decline. Alternatively, but less probable, S And might differ from the Sne Ia studied by Garnavich *et al.*

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REFERENCES

de Vaucouleurs, G., & Corwin, H.G. 1885, ApJ, 295,287

Fesen, R.A., Hamilton, A.J.S., & Saken, J.M. 1989, ApJ, 341, L55

Garnavich, P.M. *et al.* 2001 astro-ph/0105490

Leibundgut, B. *et al.* 1993, AJ, 105, 301

Phillips, M.M. 1993, ApJ, 413,L105

Phillips, M.M., Lira, P., Suntzeff, N.B., Schommer, R.A., Hamuy, M., & Maza, P. 1999, AJ, 118, 1766

van den Bergh, S. 1994, ApJ,424,345

van den Bergh, S. 2000, The Galaxies of the Local Group (Cambridge: Cambridge University Press),p.44